



**GSMaP**  
GLOBAL SATELLITE MAPPING OF PRECIPITATION

# JAXA GSMaP & Applications Status

**Takuji Kubota**

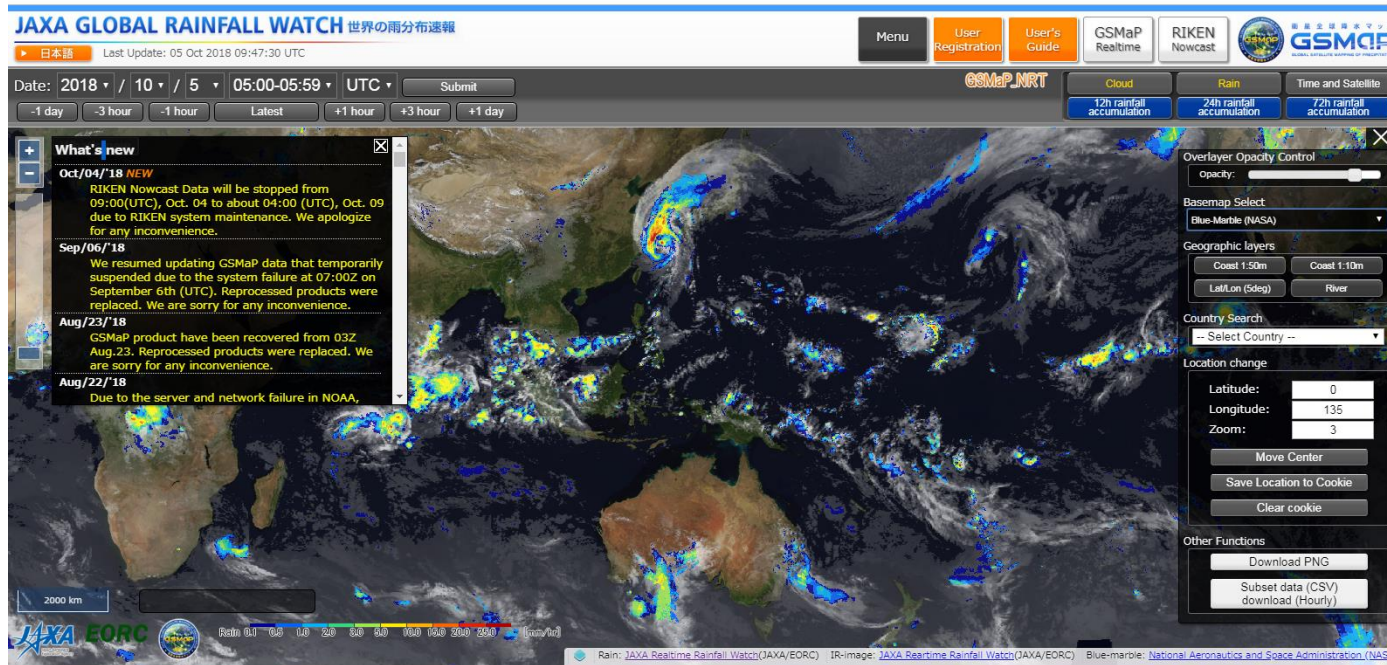
**Earth Observation Research Center (EORC)  
Japan Aerospace Exploration Agency (JAXA)**

**2020 PMM Science Team Meeting  
Oct. 2020**



# Global Satellite Mapping of Precipitation (GSMaP)

<http://sharaku.eorc.jaxa.jp/GSMaP/>



Registered  
users:  
**6620** users  
**136** counties  
(Sep. 2020)

- GSMaP is a blended Microwave-IR product and has been developed in Japan for the GPM mission.
  - U.S. counterpart is “IMERG”
  - A review paper of GPM-GSMaP V03 & V04 was published: Kubota et al. (2020), [https://doi.org/10.1007/978-3-030-24568-9\\_20](https://doi.org/10.1007/978-3-030-24568-9_20)
  - **GPM-GSMaP V05 (algorithm version 8) (including reprocessing in past 20 years) will be released in Jan. 2021.**

# Summary for improvements in GPM V05



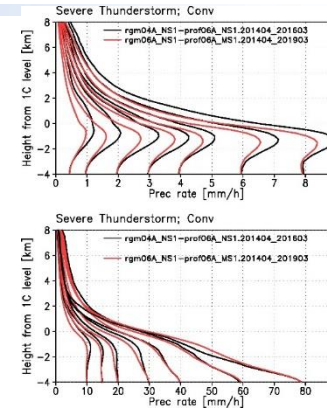
- The following improvements are expected in GPM-GSMaP V05 (algorithm version 8) released in Jan. 2021.
- **Improvements** of passive microwave (PMW) algorithm
  - Retrievals extended to the pole-to-pole
  - Update of Database
  - Heavy Orographic Rainfall Retrievals
  - PMW retrieval technique
- **Normalization module for PMW retrievals**
- PMW-IR Combined algorithm
  - **Implementation of histogram matching method by Hirose et al. (2020)**
- Gauge-adjustment algorithm
  - Based upon Mega et al. (2019), and **artificial patterns appeared in V04 will be mitigated in V05.**



# Improvements in GPM-GSMaP V05 (1)



- Updates of Database in PMW algorithm
  - Precipitation profile database
    - V04: 2-year KuPR V04A data
    - V05: 5-year DPR(MS) V06A data
  - DSD database
    - V04: Kozu et al. (2009)'s single-frequency method
    - V05: Yamaji et al. (2020a)'s dual-frequency method (Dm)
  - Precip/no-precip classification
    - V04: 2-year KuPR & GMI combined method (Seto et al. 2016)
    - V05: 5-year KuPR & GMI combined method (by Dr. Yamamoto)
  - Surface emissivity
    - V04: Furuzawa et al. (2012) using TMI & PR
    - V05: Furuzawa et al. (2012)+TELSEM (Aires et al. 2011)
  - Frozen precipitation depth
    - Newly installed in V05, presented by Dr. Aonashi at 2019 PMM Science Team Meeting.



Example of  
**2-year KuPR  
V04A vs  
5 year- DPR  
(MS) V06A**

# Improvements in GPM-GSMaP V05 (2)



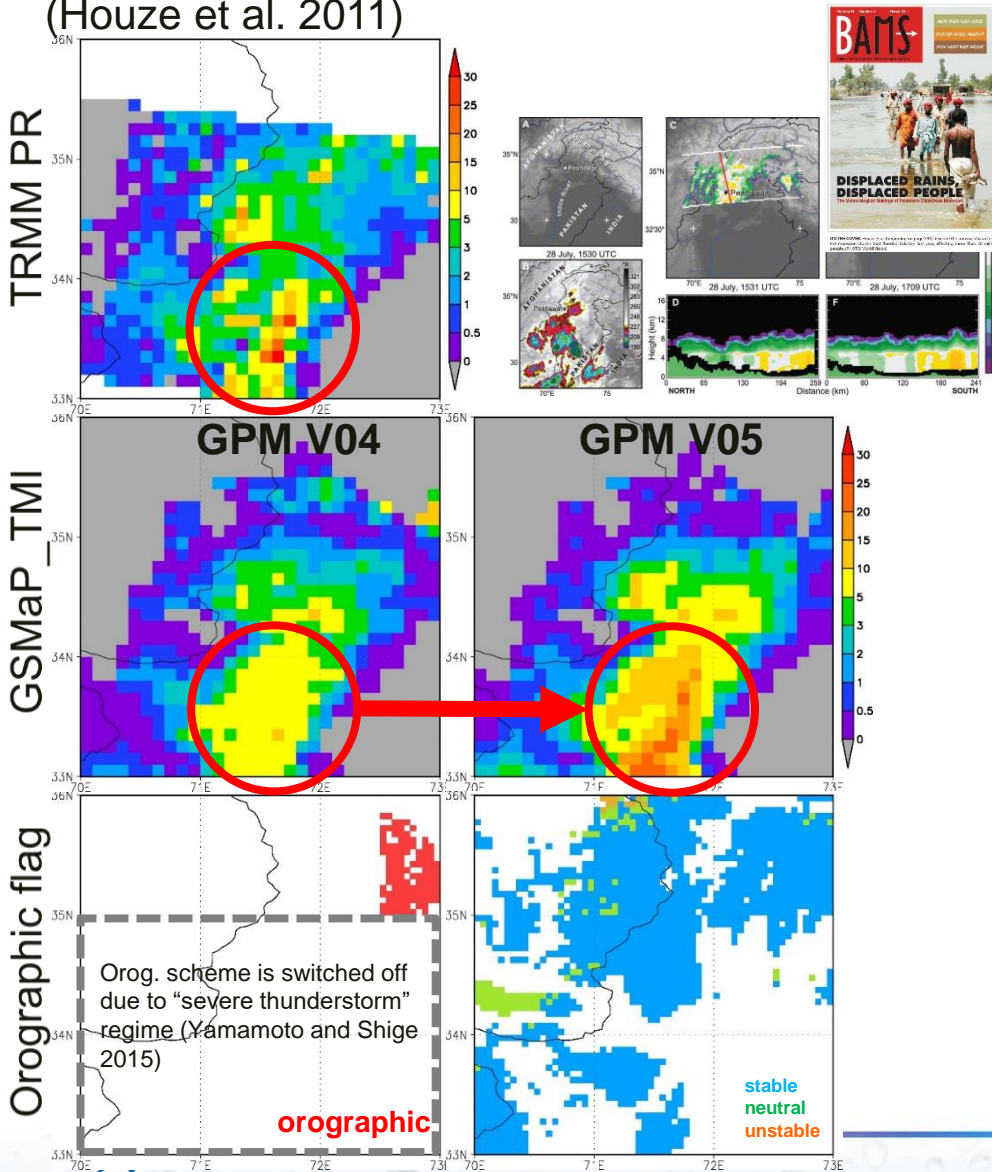
- PMW retrieval technique
  - Retrievals derived from more sensors
    - MHS(Metop-C) & ATMS (Suomi-NPP/ATMS, NOAA-20/ATMS)
  - Retrievals extended to the pole-to-pole
    - PMW retrievals only (no PMW-IR combined in 60deg-pole)
  - Dynamic land/ocean classification
    - A technique of Mega and Shige (2016) is applied to all PMW sensors.
  - Snowfall retrievals
    - Refinements of technique based upon Sims and Liu (2015) and Liu and Seo (2013) using CloudSat-DPR-GMI data
    - Improvements of screening in surface snow/sea ice
  - Precipitation detections
    - Improvements of coastal detection in MWS algorithms
- Improvements of Heavy Orographic Rainfall Retrievals
  - Presented by Prof. Shige at 2019 PMM Science Team Meeting.

# Orographic/nonorographic rainfall classification scheme in V05 (by Prof. Shige)



## Pakistan Heavy rainfall event in 28 Jul. 2010

(Houze et al. 2011)



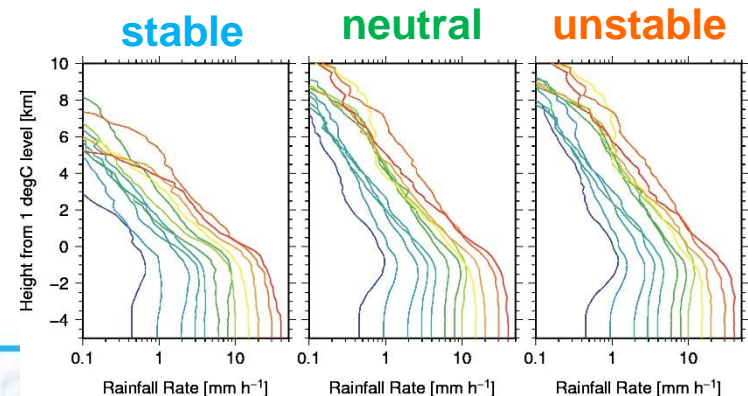
Issues of orographic rainfall scheme in GPM V04:

**Switching off of the scheme over the regions with strong lightning activity** results in underestimation of warm orographic rainfall such as Pakistan Heavy rainfall event in 28 Jul. 2010.

**Low-level static stability** (Shige and Kummerow 2016) enable the scheme to detect warm orographic rainfall over the regions with strong lightning activity

- **Stable upslope:**  $-5.5 < dT_v/dz$
- **Neutral upslope:**  $-6.5 < dT_v/dz \leq -5.5$
- **Unstable upslope:**  $dT_v/dz \leq -6.5$

$dT_v/dz$ : lapse rate of virtual temperature < 1.5 km above surface [ $K\ km^{-1}$ ]





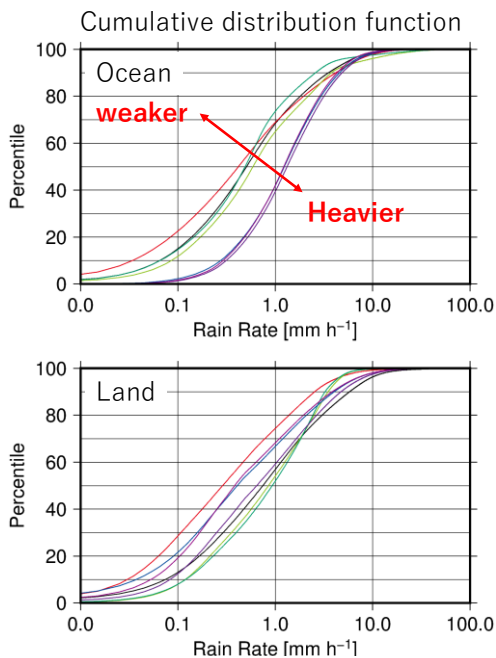
# Improvements in GPM-GSMaP V05 (3)



## ● Normalization module for PMW retrievals

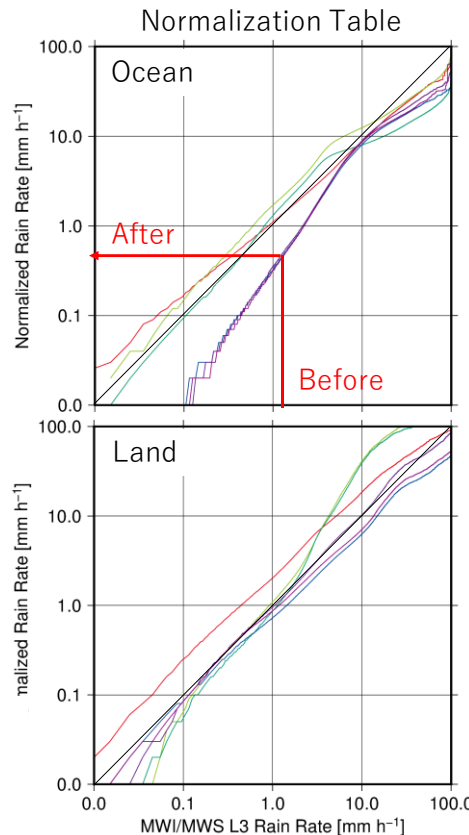
- Newly installed in V05, described in Yamamoto and Kubota (2020)

### 1. Rain-rate CDF calculated for every sensor



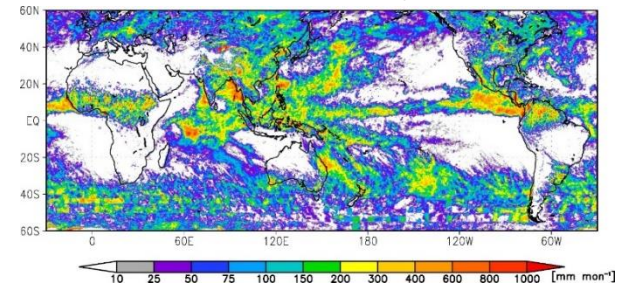
M. K. Yamamoto and T. Kubota, 2020: Development of rainfall normalization module for GSMaP microwave imagers and sounders, *Proc. IGARSS2020*.

### 2. Normalization table derived with reference to TMI/GMI

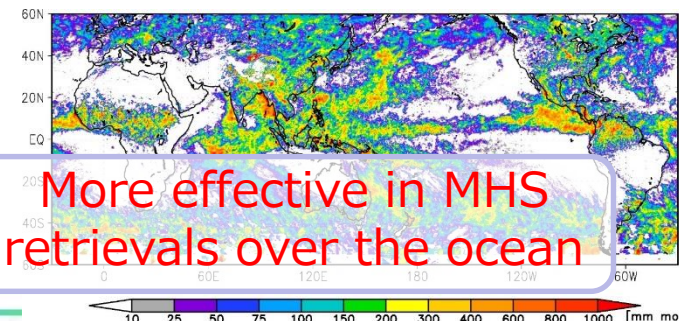


### 3. Application of the table to PMW retrievals

Mean rainfall applied by the method (F16\_SSMIS, July 2008)



Mean rainfall applied by the method (N18\_MHS, July 2008)



# Improvements in GPM-GSMaP V05 (4)



- PMW-IR Combined algorithm
  - Implementation of **histogram matching method** by Hirose et al. (2020)

## Histogram matching method

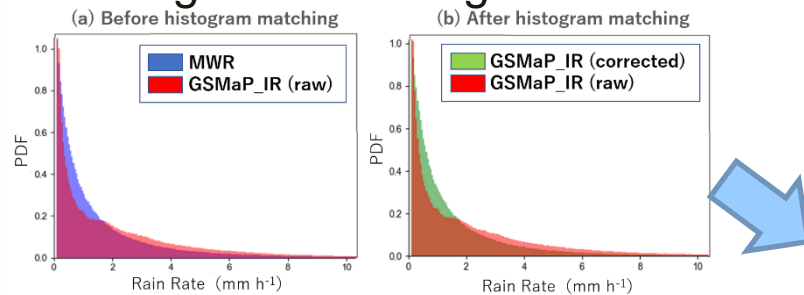


Fig. 1: (a) A rain rate histogram of MWR is shown in blue PDF and that of GSMaP\_IR is shown in red PDF. (b) Same as (a), but green PDF shows a rain rate histogram of GSMaP\_IR after applying histogram matching.

## Mitigations of spatial gaps between PMW and IR retrievals

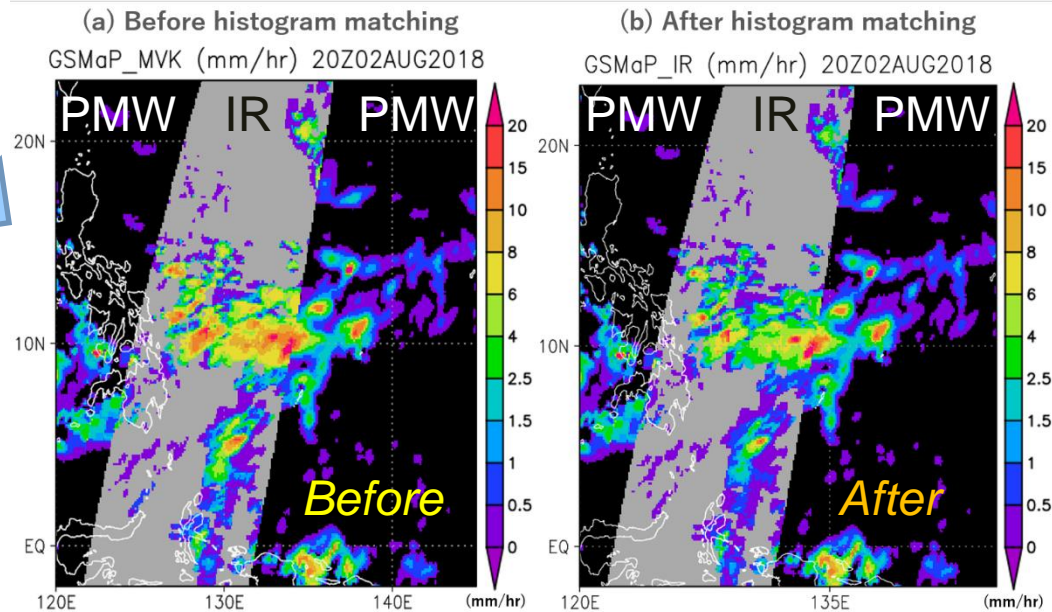


Fig. 3: (a) Snapshot of GSMaP\_MVK, black areas are observed by MWR and gray areas are interpolated by GEO IR. (b) same as (a), but histogram correction has been applied.

H. Hirose et al. 2020: Improvement for infrared rainfall estimation algorithm of GSMaP using machine learning, JpGU-AGU Joint Meeting 2020, ACG51-P05

## Mitigations of zonally averaged biases between PMW and IR retrievals

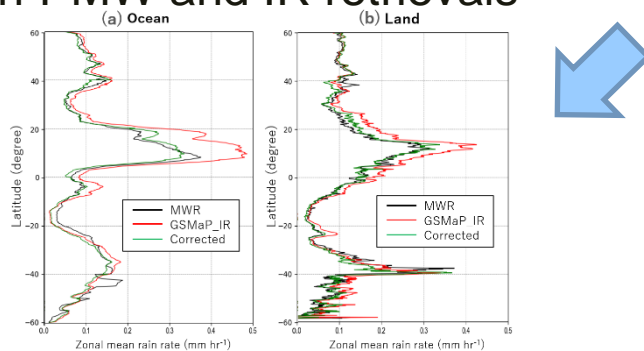


Fig. 6: Zonal mean rain rate (a) over ocean, (b) over land. Black lines show MWR results, red lines show GSMaP\_IR results and green lines show those after applying histogram matching.

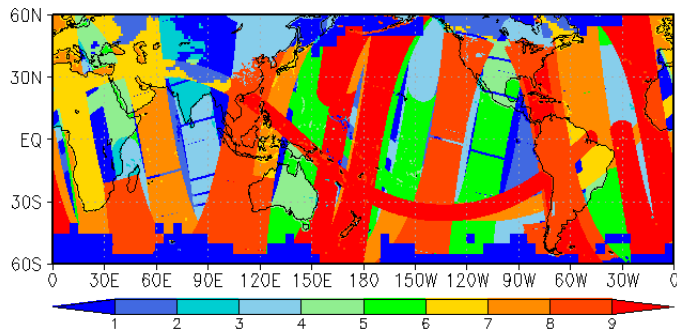




# Validation efforts: “Reliability Characterization”

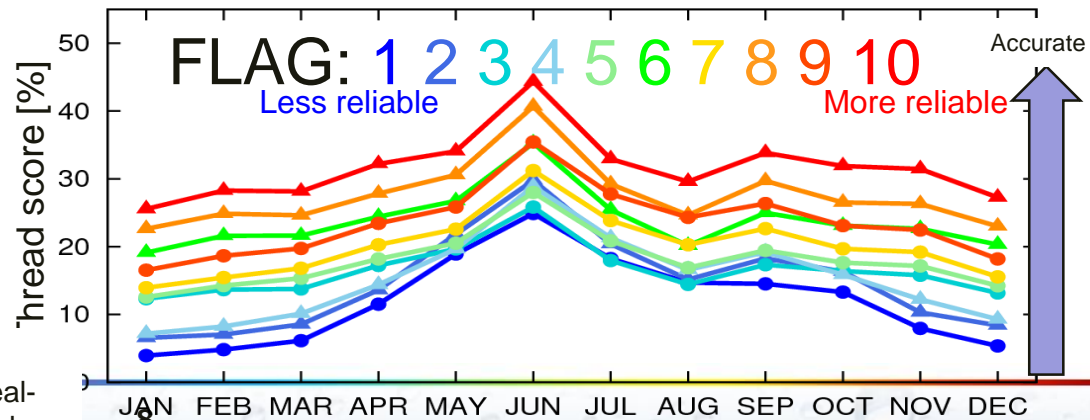
- A **reliability flag** has been available in the GSMaP since May 2017 because user communities strongly requested a measure of the reliability for the precipitation estimates.
  - 10 levels (10 being the best and 1 the worst) considering surface type reliability, low temperature reliability, and MVK propagation reliability.
  - Similar products as Quality Index for IMERG.
- Yamaji et al. (2020b, submitted) describes the reliability flag and verified the **effectiveness by classifying the GSMaP skills** with reference to ground radar data around Japan.
  - This method may be applicable also to the IMERG.

A snapshot of the reliability flag for GSMaP\_NRT



M. Yamaji, T. Kubota, and M. K. Yamamoto, 2020b: An Approach to Reliability Characterization of GSMaP Near-Real-Time Precipitation Product, *J. Meteor. Soc. Japan*, submitted.

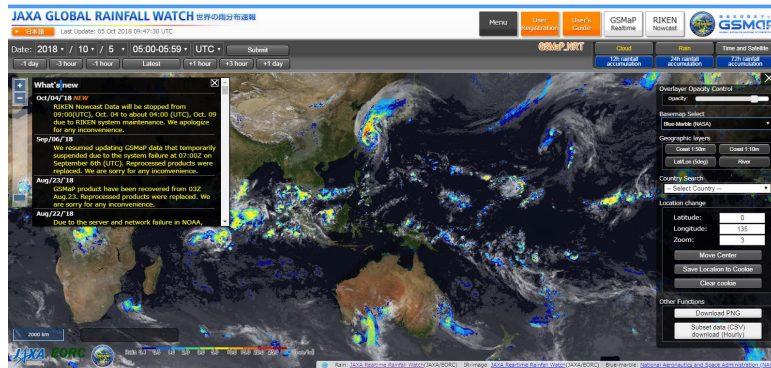
Seasonal march of thread score for each level of the flag



# GSMaP utilization and application



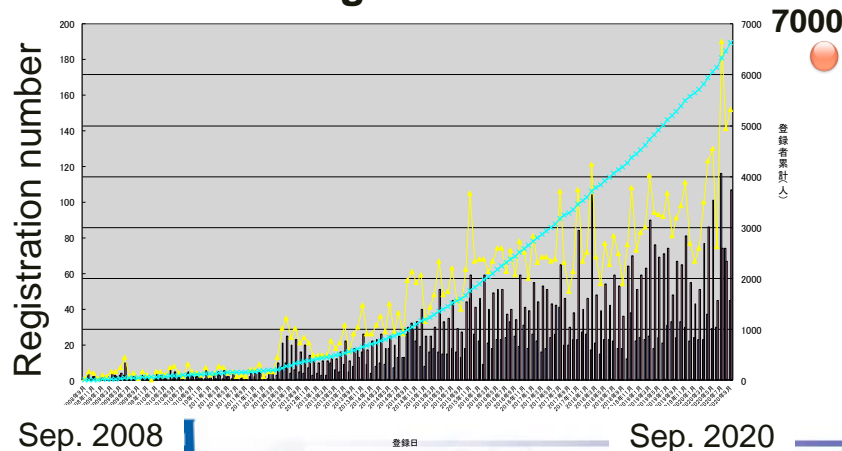
The GSmAP by the JAXA has been used in various applications!



<https://sharaku.eorc.jaxa.jp/GSMaP/>

**6620 registered users from 136 countries**  
(as of Sep. 2020)

## GSMaP registered numbers



## Weather monitoring

- Meteorological agencies in Asia/Oceania country
- World Meteorological Organization (WMO) project
- Weather company (JWA)

## Flood warning/prediction

- International Flood Network (IFNet), Infrastructure Development Institute (IDI) : Global Flood Alert System (GFAS)
- International Centre for Water Hazard and Risk Management (ICHARM) : Integrated Flood Analysis System (IFAS)
- UNESCO-IHP: flood warning system using IFAS
- Asia Development Bank (ADB): River management including flood risk
- Japan International Cooperation Agency (JICA)

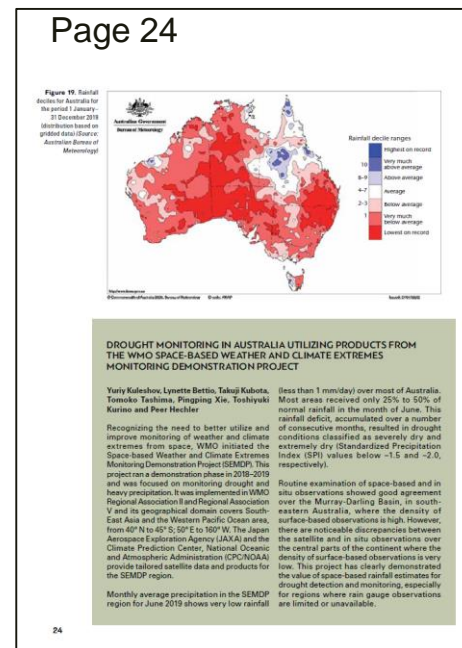
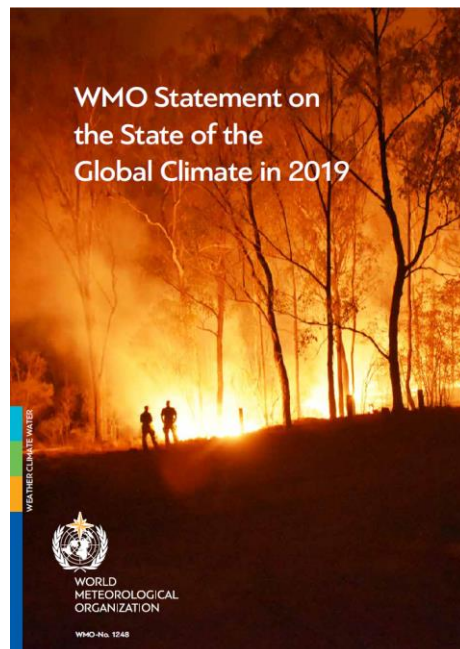
## Agriculture

- MAFF (Ministry of Agriculture, Forestry and Fisheries in Japan) for watching crop situation in the world.
- Asia-RiCE (Asia Rice Crop Estimation & Monitoring) for GEO Global Agricultural Monitoring (GEOGLAM)
- Agricultural Insurance

# World Meteorological Organization (WMO) Statement on the State of the Global Climate 2019



- **WMO Space-based Weather and Climate Extremes Monitoring (SWCEM) Demonstration Project (SEMDP)**, East Asia and Western Pacific Regional Subproject initiated in 2018 (Kuleshov et al. 2019, DOI:10.5772/intechopen.85824).
- JAXA attends this subproject with the GSMaP and provide the GSMaP\_Gauge\_NRT product with 20yr-climate normal.
- Based upon results of this project, results from JAXA GSMaP and NOAA CMORPH were described in the 2019 Australia drought article of the **WMO Statement on the State of the Global Climate 2019**.



DROUGHT MONITORING IN AUSTRALIA UTILIZING PRODUCTS FROM THE WMO SPACE-BASED WEATHER AND CLIMATE EXTREMES MONITORING DEMONSTRATION PROJECT

Yuriy Kuleshov, Lynette Bettio, Takuji Kubota, Tomoko Tashima, Pingping Xie, Toshiyuki Kurino and Peer Hechler

WMO Secretary-General Petteri Taalas at UN headquarters in New York (11<sup>th</sup> Mar. 2020)



<https://public.wmo.int/en/media/news/state-of-climate-report-released-un-and-wmo-chiefs>

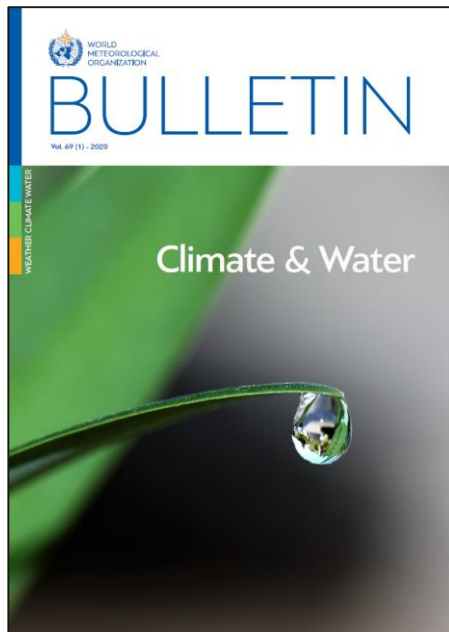
<https://public.wmo.int/en/our-mandate/climate/wmo-statement-state-of-global-climate>  
[https://library.wmo.int/doc\\_num.php?explnum\\_id=10211](https://library.wmo.int/doc_num.php?explnum_id=10211)



# SEMDP Article in WMO Bulletin



- Results of the SEMDP using GSMAp and CMORPH data were described in the WMO Bulletin (the official journal of the WMO).
- <https://public.wmo.int/en/resources/bulletin/wmo-space-based-weather-and-climate-extremes-monitoring-demonstration-project>



WMO Bulletin Vol 69  
(1) - 2020



## WMO Space-based Weather and Climate Extremes Monitoring Demonstration Project for East Asia and Western Pacific

By Yuriy Kuleshov<sup>1</sup>, Takuji Kubota<sup>2</sup>, Tomoko Tashima<sup>3</sup>, Pingping Xie<sup>4</sup>, Toshiyuki Kurino<sup>5</sup>, Peer Hechler<sup>4</sup> and Lisa V. Alexander<sup>4</sup>

Meteorological observations clearly demonstrate that global climate change has occurred since the beginning of the Industrial Revolution. That change has been particularly pronounced since about 1950, and includes changes in weather and extreme climate events. Changes in weather and climate extremes can significantly increase the impacts on society, leading to a greater number of disaster worldwide. One of the world's most disaster-prone regions is the Asia-Pacific. Since 1970, disasters have killed two million people in the Asia and Pacific region – 59% of the global death toll. The most frequent natural hazards in the region are hydro-meteorological events [1]. There is a pressing need to develop and implement new tools for global monitoring of these increasingly frequent and severe hazardous phenomena, including using modern satellite remote sensing techniques.

Recognizing the importance of this issue, WMO launched a two-year (2018–2019) Demonstration Project on space-based weather and climate extremes monitoring. The project is focused on drought and heavy precipitation over the South-East Asia region and the Pacific Ocean. In June 2019, the Eighteenth World Meteorological Congress (Cg-18) reviewed the outcomes and recommended the expansion of the project to other WMO regions and adopted

an implementation plan to transition it into an operational phase. This article highlights the outcomes of the Demonstration Project in two Australian case studies: during the Millennium Drought and extreme precipitation events during the 2010/2011 La Niña event.

### Knowledge transfer essential

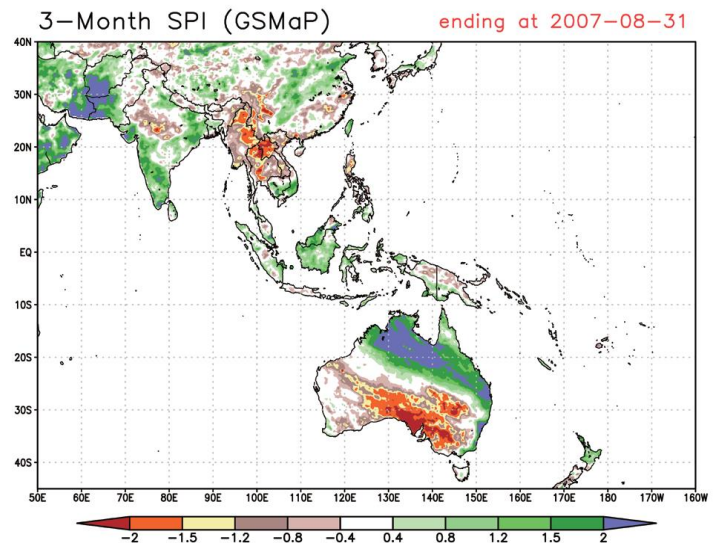
The Demonstration Project was set up following the recommendations from a February 2017 WMO workshop on Operational Space-based Weather and Climate Extremes Monitoring. The workshop gathered representatives from satellite operators, research and development agencies, WMO Regional Climate Centres (RCCs) and National Meteorological and Hydrological Services (NMHSs) to stimulate a dialog about enhancing utilization of space-based observation data and products for monitoring weather and climate extremes.

The workshop recognized that many developing and least developed countries were not benefiting from the significant progress made in space-based observations in most geographical domains – several high-resolution satellite products are available on a quasi-real time basis, enabling enhanced use for monitoring weather and climate extremes from space. Participants recommended the strengthening of human and technological capacity through knowledge transfer in order for all countries to benefit fully from the advantages of modern space-based data and derived products. The RCCs could

- 1 The Australian Bureau of Meteorology, Australia
- 2 The Earth Observation Research Center, Japan Aerospace Exploration Agency (JAXA), Japan
- 3 The Climate Prediction Center, National Oceanic and Atmospheric Administration (NOAA), USA
- 4 WMO Secretariat
- 5 UNSW Sydney, Australia

## WMO Space-based Weather and Climate Extremes Monitoring Demonstration Project for East Asia and Western Pacific

Kuleshov, Y., Kubota, T., Tashima, T., Xie, P., Kurino, T., Hechler, P., Alexander, LV

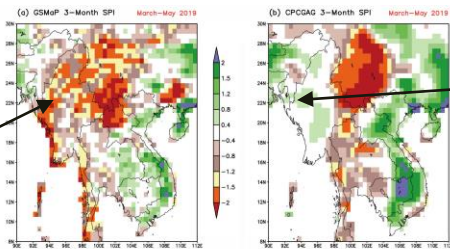


# A paper for precipitation extremes monitoring using the GSMaP



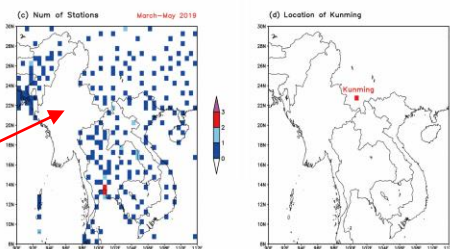
- Based upon experiences of the SEMDP, a peer-review paper (Tashima et al. 2020) was published for precipitation extremes monitoring using the GSMaP GNRT6.
  - T. Tashima, T. Kubota, T. Mega, and T. Ushio, and Riko Oki, 2020: Precipitation extremes monitoring using the near-real-time GSMaP product, *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, <https://doi.org/10.1109/JSTARS.2020.3014881>.
- In the paper, we pointed out an issue in Myanmar, with no available rain gauges in the NOAA/CPC gauges.

3-mon  
Standardized  
Precipitation  
Index (SPI) by  
GSMaP in  
March-May 2019



3-mon SPI by  
NOAA/CPC  
Gauges in  
March-May  
2019

No available  
rain gauges  
in Myanmar



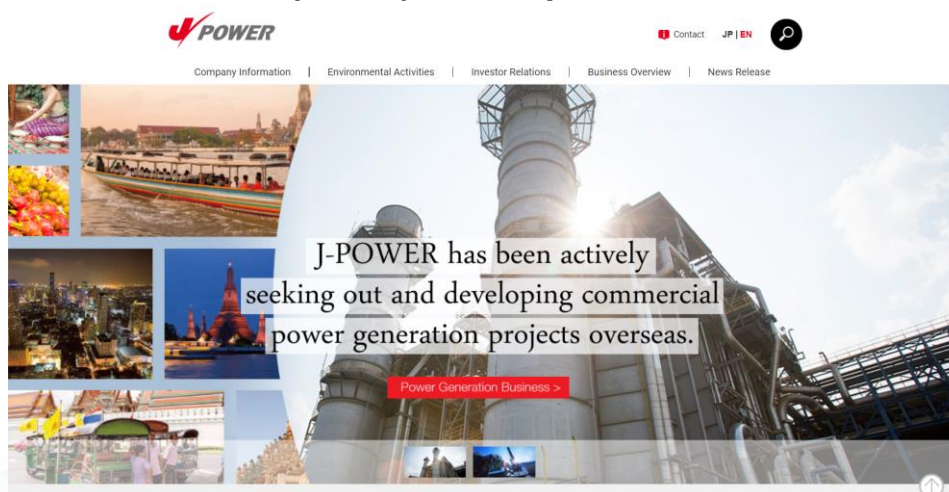
This clearly demonstrates the value of space-based rainfall estimates for drought detection and monitoring, especially for regions where rain gauge observations are limited or unavailable.



# Hydropower development planning



- Since 2018, the JAXA and the J-Power (Electric Power Development Company in Japan) have studied the **hydropower development planning** using the GSMaP data.
- A joint paper by the J-Power and the JAXA will be published in November 2020.
  - The paper describes the GSMaP data can be helpful in the **hydropower development planning** with consideration of error tendencies (sorry for the Japanese language) .
    - Mori, T., S. Nakamura, and M. Yamaji, 2020: Potential use of Global Satellite Mapping of Precipitation (GSMaP) for River Runoff Estimation in Hydropower Development Studies. Electric Power Civil Engineering. *(in Japanese)*



J-Power (Electric Power Development Company in Japan)

<https://www.jpowers.co.jp/english/>



# Applications for NWP and the hydrological simulations in the JAXA



- NWP assimilation of the GSMaP in JAXA supercomputer system

“**NEXRA**”

- with Univ. Tokyo and RIKEN (Kotsuki et al. 2019, SOLA)
- <https://www.eorc.jaxa.jp/theme/NEXRA/>

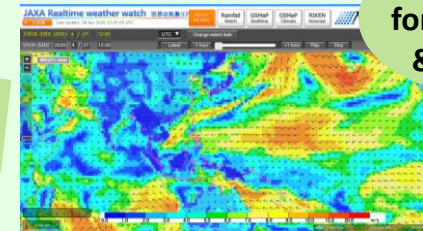
- Global hydrological simulation system “**Today's Earth (TE)**”

- with the joint research with Univ. of Tokyo.
- <https://www.eorc.jaxa.jp/water/>

**GSMaPxNEXRA** based upon Kotsuki et al. (2019, WAF) started in Aug. 2020. (<https://sharaku.eorc.jaxa.jp/GSMaPxNEXRA/index.htm>)

with U. Tokyo, RIKEN

New technology for assimilation & prediction



**NEXRA**

Numerical Weather Prediction (NWP) Model



Satellite Data



GSMaP Down SW

Land/River Model



with U. Tokyo

Drought, Flood, Water-related Hazard



# GPM Asia-Oceania Workshop

- The 8<sup>th</sup> GPM Asia-Oceania Workshop on Satellite Precipitation Data Utilization
  - was planned with Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) in Manila, Philippines, on 12-13 Mar. 2020.
  - (renamed as “GPM Asia Workshop” → “GPM Asia-Oceania Workshop”)
- Purpose of the workshop:
  - To promote satellite precipitation data utilization in Asia-Oceania, and move forward research activities related to GPM in each country in working-level.
  - To share early validation and utilization results of the GPM products in Asia-Oceania.
  - To proceed future collaborations between Japan and Asian-Oceania countries.

**Postponed due to the COVID-19 pandemic**



# Summary



- GPM/GSMaP status
  - <https://sharaku.eorc.jaxa.jp/GSMaP/index.htm>
  - A new version (including reprocessing in past 20 years) will appear in **Jan. 2021**.
    - Algorithm improvements are summarized here.
- Applications status
  - **WMO SEMDP with GSMaP and NOAA/CMORPH.**
    - WMO Statement on the State of the Global Climate 2019
    - The Article in WMO Bulletin
    - Tashima et al. (2020, *IEEE JSTARS*)
      - <https://doi.org/10.1109/JSTARS.2020.3014881>.
  - Hydropower development planning using the GSMaP
  - JAXA is operating and providing the NEXRA & the TE.
  - GPM Asia-Oceania Workshop with the PAGASA, Philippine in **was postponed due to the COVID-19 pandemic.**